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MEASUREMENTS OF FLOW PHENOMENA INDUCED BY SUCTION THROUGH PERFORATED AND PARTIALLY PLUGGED SURFACES

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WORK PERFORMED

Efforts during the second six months of the project have been directed towards completing construction of the wind-tunnel test section, assembling instrumentation, programming the data acquisition and reduction system, adjusting the streamwise pressure gradient of the test section, calibrating the hot-wire anemometer probe, and constructing and testing a smoke generator.

The test section was described in the previous progress report. It has been installed in the wind tunnel and is completely operational. The streamwise pressure gradient was adjusted to be nominally zero at a free-stream velocity of 3.05 m/s (10 ft/s). This was accomplished by adjusting the upper wall of the test section to be slightly divergent. The change in static pressure between any two streamwise locations in the test section was less than one percent of the free-stream dynamic pressure. This is considered adequate for these experiments.

Considerable time was required to establish a suitable means for accurately calibrating the hot-wire probe which is used to measure boundary-layer velocity profiles and fluctuating velocities. Four different calibration techniques were tried before a suitable method was reached. Each method is described on the following pages.

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The first and simplest technique considered was to assume that the wire obeyed Kings law:

$$E^2 - E_o^2 = A\ U^n \tag{1}$$

where E is the anemometer output at velocity U; E_o is the output at $U = 0$; and A and n are calibration constants with $n \approx 0.5$. It is known that the value of n is a weak function of velocity; however, it was not known how great the variation was for the velocity range of these experiments. The pressure transducers used to measure the free-stream velocity were not capable of accurately resolving the very small pitot pressures corresponding to velocities below about 1.5 m/s (5 ft/s). The probe could not, therefore, be calibrated in place. It was evident then that a separate calibration facility capable of producing very low, accurately measurable velocities was required.

The next technique tried was to build a small, open-loop wind tunnel using components which were readily available. The tunnel is shown in figure 1. In principle, the air was drawn through the bell mouth inlet and into a test region of accurately known diameter. The total mass flow was measured with a flowmeter (Gilmont ball type rotameter) from which the velocity at the probe could be calculated. This calibration technique was unsuccessful for several reasons. The first was that the uncertainty in the mass flowmeter readings was more than the ±2 percent quoted by the manufacturer. (The additional uncertainty was due to correcting the flowmeter calibration curves to local test conditions). Also, the very low velocities of interest required that a viscous correction due to the tunnel boundary layer be made on the calculated velocity. This correction had to be determined experimentally and was a function of velocity, making the calibration method overly complex. Another problem with this method was that minor room air currents disturbed the flow into the bell mouth, causing unsteadiness in the flow at the probe. The method was therefore abandoned.

The third method tried for probe calibration, again using only components which were readily available, was to move the probe through still air. A rotating arm was used for this purpose and is shown in figure 2. In principle, the probe was attached to the end of an arm which could be rotated by hand. The entire assembly was enclosed in a box with a small access hole on top to avoid room air currents. The probe velocity could be determined from the radius of the arm and the rate of rotation. The rate of rotation was determined by numerically differentiating the digitized potentiometer output with respect to time. The anemometer output was also digitized and was plotted as a function of probe velocity at equal points in time to provide the calibration curve. The digitizing was done with a Neff System 620 Digital Signal Processor, which sampled each input at a constant rate of 1906.2 samples/s. To avoid the problem of recirculating air currents within the box, the probe was accelerated to its maximum velocity in one turn or less.

The method proved to be basically successful as far as calibrating the probe was concerned, but presented certain drawbacks as a routine method of calibration. Most significantly, the A-D converter and computer were not located in the same building as the wind tunnel. This lead to large differences between the ambient temperature at calibration and that during tunnel operation. The temperature change can be approximately corrected for but adds additional uncertainty to the data. Another problem was that the setup time for a calibration was long and involved transporting equipment from one building to another and rewiring of the A-D converter inputs which were being used in other experiments. The method did prove, however, that moving the probe through still air was an accurate and simple technique of probe calibration.

The method finally adopted for calibration used a pendulum and simple timing circuit to avoid the expense of the A-D converter used in the previous method. The apparatus is shown in figure 3. A compound pendulum with an equivalent 2-m (6.56-ft) simple pendulum

length was used, enclosed in a large closet to avoid room air currents. The probe was attached to a movable slide which could be positioned at any point along the pendulum rod. In operation the pendulum was drawn back to some starting angle by means of a drawstring and released. When the probe passed its lowest point, the pendulum triggered a simple photoelectric timing circuit to measure the time required for the pendulum to pass and also triggered a digital voltmeter to read the anemometer output. By repeating this procedure for different starting angles and probe positions along the pendulum, a complete calibration curve from 0.06 to 4 m/s (0.2 to 13.1 ft/s) could be obtained. The only problem encountered with this method was a vertical temperature gradient in the still air in the box due to the cold floor. That problem was solved by insulating the floor.

The estimated accuracy of velocities measured with this method is better than 0.5 percent of reading over the entire velocity range. The facility is located in the same room as the wind tunnel, which allows for quick and frequent calibrations and calibration checks.

Calibrations conducted using the pendulum method have shown that equation (1) is not valid for a single value of n over the velocity range of interest and a modified equation is required:

$$E^2 - (BE_o)^2 = C + D\,U^n + F\,U^{2n} \tag{2}$$

where B, C, D, and F are calibration constants and $n = 0.5$. At this time, a calibration based on equation (2) has not been used to measure a boundary-layer velocity profile in the tunnel. Based on the accuracy of the method, however, and the goodness of the curve fit of equation (2), no further problems are foreseen.

The final effort during this report was the construction and benchtesting of a smoke generator. This generator will be used later in the program for flow-visualization studies. The smoke generator is shown in figure 4. It consists basically of

an oil supply pumped to a heated tip within a holding chamber where a dense smoke is formed. Compressed air and inlet and outlet control valves control the flow of smoke. Benchtesting has shown that the device is capable of delivering a visible, continuous filament of smoke into a moving air stream.

FUTURE EFFORTS

The first work to be conducted in the next report period will be to obtain a detailed velocity mapping of the test section using the pendulum-method calibration. Following this, the flow downstream of a 2-D slot with suction will be examined and compared to existing results. A blocked 2-D slot will be examined using the smoke generator, and detailed, single hot-wire measurements will be made. A three wire, hot wire probe for spatial flow studies is being constructed, and provisions are being made to introduce artificial disturbances into the slots' suction plenum chamber for future studies.

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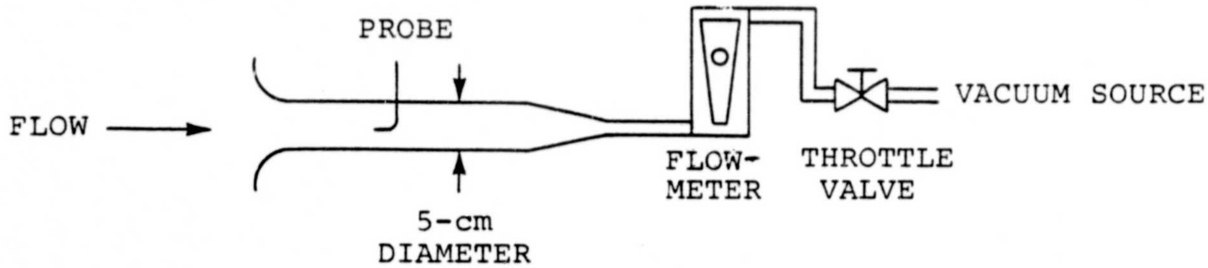

Figure 1. Wind tunnel for hot-wire calibration.

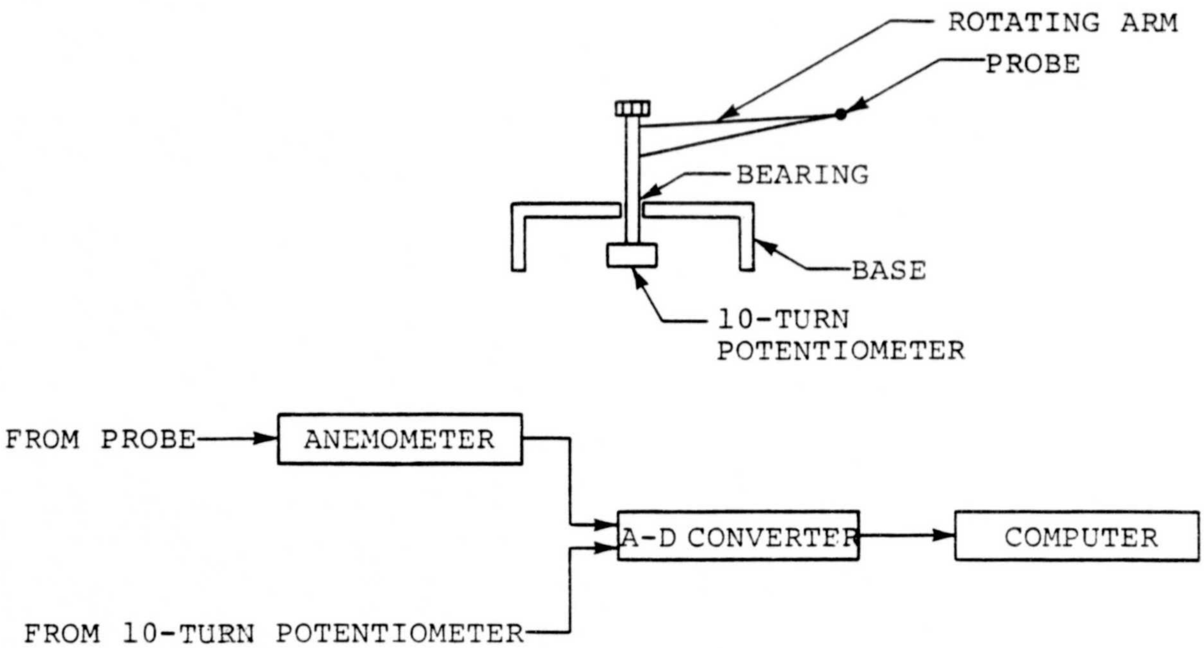

Figure 2. Rotating arm for hot-wire calibration.

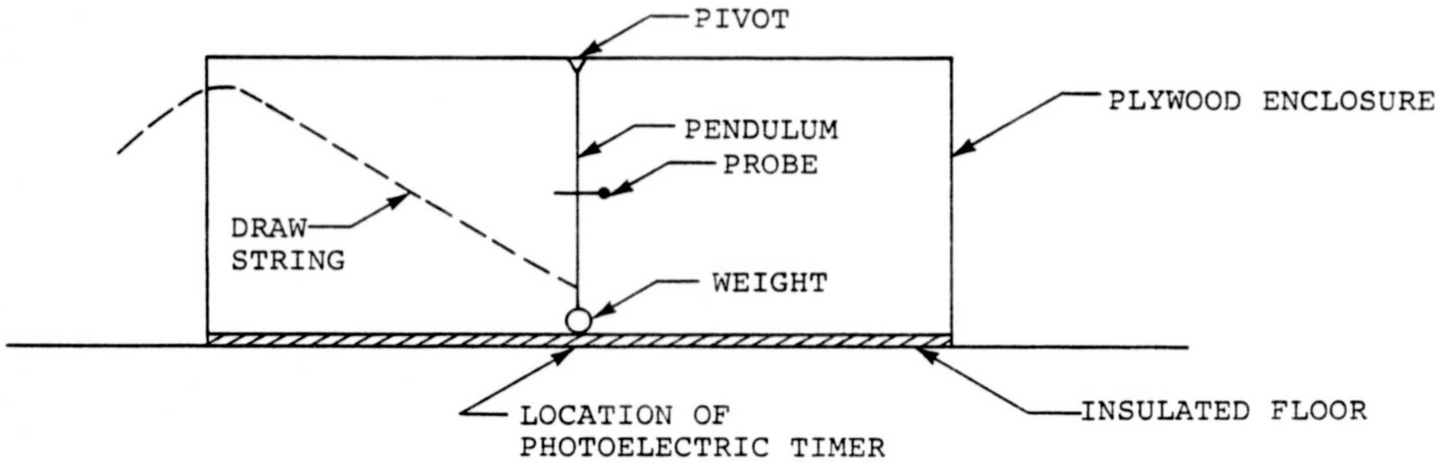

Figure 3. Pendulum facility for hot-wire calibration.

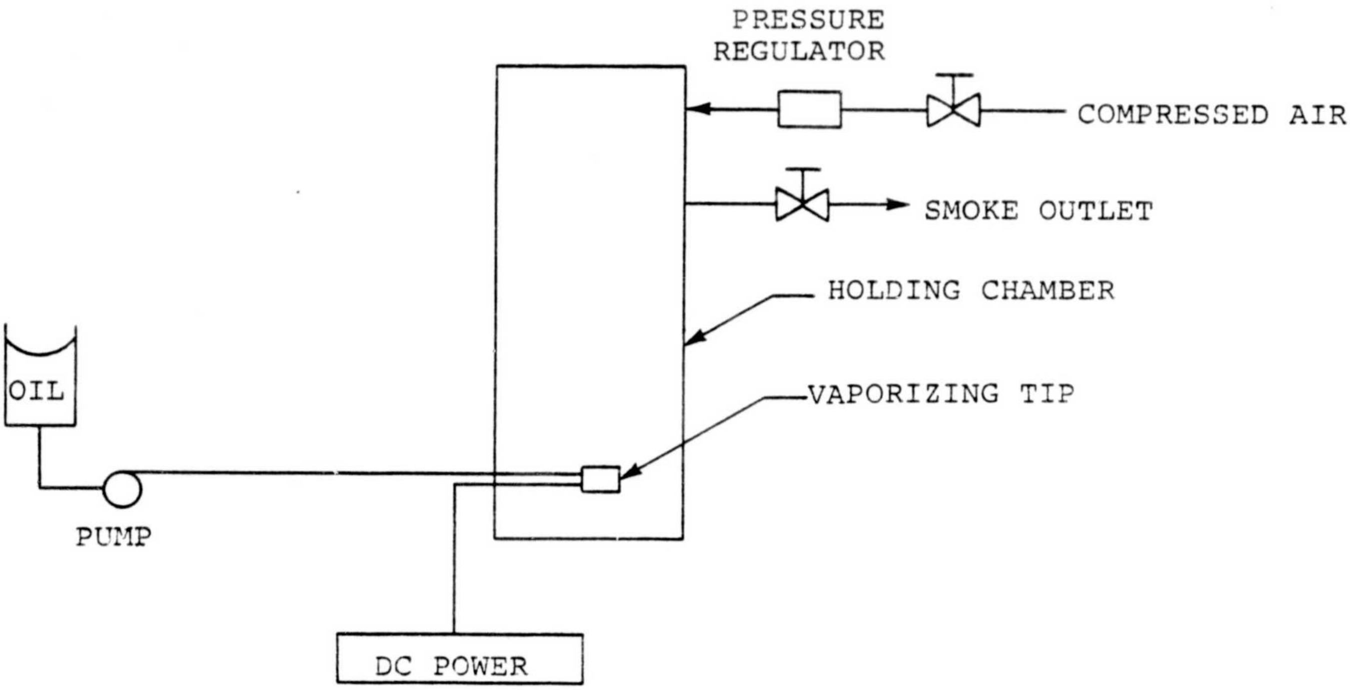

Figure 4. Smoke generator.